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FUZZY LOGIC APPROACH TO PETROLEUM PRODUCTS BUYING DECISION IN GHANA (A CASE OF PRIVATE CAR OWNERS IN ACCRA, GHANA)

JOHN BOSCO K. DAMNYAG[1], PAUL AAZAGREYIR[2] & MARCELLINUS KUUBOORE[3]

[1,2]Department of Information Technology Studies, University of Professional Studies, Accra, Ghana

[3]Department of Computer Engineering, University of Ghana, Accra, Ghana

ABSTRACT

The degree of fuzziness and subjectiveness inherent in buying decision making is complex and difficult to measure. This paper deploys a fuzzy logic approach to petroleum products buying decision making by vehicles' drivers in Ghana. It has been argued that un-strategic petroleum products buying decision in terms of amount to buy, distance to travel and the engine capacity of the car leads to stress and financial loss by drivers. The main objective of this study is to provide a fuzzy logic approach to the petroleum products buying decision to minimize cost and stress among drivers to ensure effective and efficient delivering of their duties. The study uses three input variables as the input membership function and one output variable as the output membership function. The membership functions are triangular with 15 fuzzy rules in the development of an evaluation model.

KEYWORDS: Petroleum Products, Buying Decision, Fuzzy Logic, Fuzzification & Defuzzification

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Original Article

1. INTRODUCTION

In the real world, decisions are made every day, and the decision-maker has the difficult task of choosing among the many alternatives and specifying the optimal one (Maurizio & Alberto, 2010). Ghanaians including private drivers are faced with so many options to decide with regards to petroleum products buying on a daily basis. According to Campbell, Whitehead, and Finkelstein (2009), decision making is influenced by the personal characteristics of the people involved, which should be noted and managed to minimize bias. Personal decisions may be taken vaguely by the decision-maker. Buying decisions are usually based on rational factors as well as subjective variables. The rational factors include geographical location, lead time and price. The subjective variables include buyers' lifestyles, interests, activities, quality, personal values, and others.

The busy nature of some private car owners among others precludes them from properly making an excellent fuel buying decision for their cars. If buying decisions are properly made that may yield vast fortunes and if made inaccurately, it may lead to financial loss and stress (Gupta, 2013). According to Fuel (n.d.), about 80% of buying decisions are made emotionally and 20% are made logically. Drivers who made emotional decisions instead of logical ones face a lot of challenges including financial loss and stress. To avert these challenges, it is therefore imperative to develop a fuel buying decision model for drivers. The decision model is hence the most germane decision support system which drivers ought to take seriously, if they want to make informed decisions that are optimal.

2. PROBLEM STATEMENT

Many drivers in Ghana are faced with stress and financial loss due to their inability to make an excellent fuel buying decision. The assumption is that the proper buying decision-making process is not done by the drivers, thus, resulting in bad buying decisions. According to Abdulrahman, Panford, and Hayfron-acquah (2014), majority of drivers make subjective self-judgment concerning their buying decision which leads to inconsistencies and biases resulting in wrongful fuel buying decisions.

In this literature, various rational factors and subjective variables have been used to aid in buying decision making. These factors and variables alone are incomplete to enhance any excellent buying decision process. A good buying decision process necessitates the involvement of key rational factors, subjective variables and a logic approach like fuzzy logic to assist in making which is not excellent but good fuel buying decision by the drivers.

3. RELATED WORK

The fuzzy Logic tool was introduced in 1965, by Lotfi Zadeh, is a mathematical tool for dealing with uncertainty. Fuzzy logic means approximate reasoning, information granulation, computing with words using linguistic terms and others (Sivanandam, Sumathi, & Deepa, 2007). According to Abdul Rahman, Panford and Hayfron-acquah (2014), fuzzy logic is applicable in domains such as credit scoring, medicine, artificial intelligence, decision theory, operations research, and host of other applications. It has the capacity of handling imprecision, vagueness and can effectively describe information from Zero (0) to One (1). Decision making has also witnessed some applications of fuzzy logic to assist in making excellent decisions.

Sevastianov and Dymova (2009) presented synthesis of fuzzy logic and Dempster-Shafer Theory for the simulation of the decision-making process in stock trading systems. Lin and Hsieh (2004) presented a fuzzy decision support system for strategic portfolio management. Kuo, Chen, and Hwang (2001) studied an intelligent stock trading decision support system through integration of genetic algorithm based fuzzy neural network and artificial neural network.

4. METHODOLOGY

4.1 Data Collection

Private car owners in Accra were used as the case study for this research. Madina is a suburb of Accra and in the La Nkwantanag Municipal Assembly. A municipality in the Greater Accra Region of southeastern Ghana. The observation was used to collect data on drivers in Madina.

4.2 Research Process

Three input variables were identified to help in the buying decision-making process. The input variables are: amount, distance and engine capacity. These variables formed the input membership function for the fuzzy logic model.

Amount: The amount of money the driver has and wants to buy the fuel at a standardized price and quantity. The aim is to minimize the cost for traveling a long distance and using a small amount of money to buy fuel.

Distance: The length of distance in kilometers the driver moves to buy the fuel at a standardized price and quantity. The aim is to buy the fuel at the least distance that is traveling a short distance to purchase the fuel.

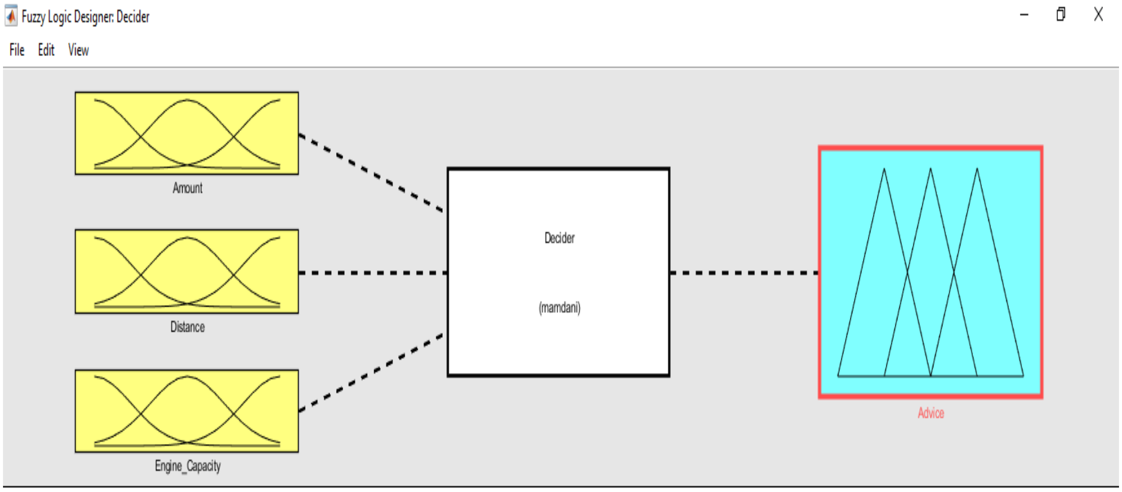

Figure 1: Fuzzy Logic Design of the Membership Fuunctions(Both Input and Output) using the Mamdani Fuzzy Inference System.

Engine Capacity: Is the measurement of how large the space in which the car engine pistons operate. A bigger number means each piston can push more air and fuel through the car's engine every time it moves (Haining, 2019). Engine capacity is measured in liters.

All the three input variables are given linguistic terms such as small/short, average/midsize, big/long depending on the fuzzy value threshold. The input variables were assigned weights as 45, 35 and 25, respectively. Consequently, an output variable (Advice) was identified to serve as an output membership function which was also given threshold value (Abdulrahman, Panford, & Hayfron-acquah, 2014)

Moreover, 15 Fuzzy rules were created using the fuzzy Min-function. These rules are the various possible combinations of the input variables using the fuzzy and operator with their fuzzy values. These rules eventually served as the guide for evaluation of the fuel buying decision. Finally, the Centroid Defuzzification method was chosen to find the crisp output which provides the decision to the driver for buying the fuel. The centroid is repented mathematically as.

$Centroid = \frac{\Sigma\mu v(yi)y}{\Sigma\mu v(yi)}$ where $\mu v(yi) =$ membership value in the membership function and $y =$ centre of memberships function.

4.3 Software Tool

Matlab R2019a which stands for Matrix Laboratory Released 2019 version A is a powerful scientific tool used for various works including the modeling of fuzzy system. It was used to simulate the model. The various input membership function (Amount, Distance, Engine-Capacity) and the output function (Advice) were captured. The various rules were also captured in the system too.

5. IMPLEMENTATION

The user interface is the first stage where the user interacts with the system. It helps the user communicate with the system effectively. This is done through the use of the keyboard or a phone to enter information into the system.

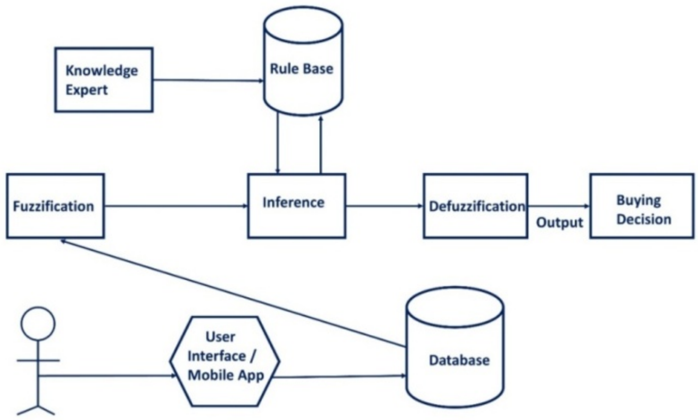

Figure 2: Detail Architecture of the Model.

The Database/Mobile Application contains information such as amount, distance and engine capacity in the database.The database is normalized and efficiently support queries and ad hoc queries posed to the system. The fuzzifier picks individual driver detail information on amount, distance and engine capacity from the database. These are converted as fuzzy values and kept within the system.

The Fuzzification process is expected to convert the crisp input (from the database) values into a fuzzy set. Three input variables were used. The input variables had given a percentage scale to represent. An input membership functions are constructed indicating the threshold of all the three input variables which helped in building the rules for the system. Tables 1–3 show the input membership function and their linguistic terms. Figure 2 describes the duration of input membership function with threshold for small/short, average/midsize, big/long.

The rule base or knowledge base contains various rules constructed in consultation with a knowledge expert. These rules form the actual working rules for the fuzzy controller. Based on the input and output membership functions, 15 rules were generated. Using the Mamdani Inference System with the Min-Operator (see appendix I for the rules).

The Defuzzification process outputs the aggregated function as crisp values using the centroid method. The centroid finds the Centre of gravity of the aggregated values.

Table 4 describes the output membership function. The output membership function contains only one variable namely Advice and its range of fuzzy values and defined linguistic term.

Table 1: Input Membership (Amount)

Range of Price Values (GhȻ)	Fuzzy Values (0 1)	Converted Range of Values (%)	Linguistic Term
1–20	0.02–0.33	2–33	Small
21–40	0.35–0.66	35–66	Average
41–60	0.68–1	68–100	Big

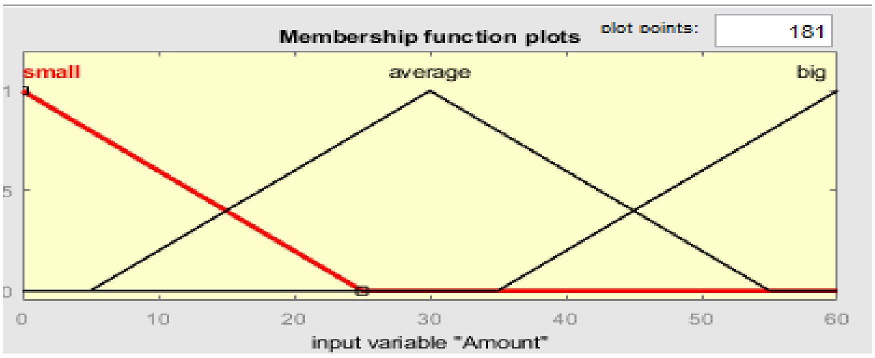

Figure 3: Input Membership (Amount).

Table 2: Input Membership (Distance)

Range of Distance Values (Km)	Fuzzy Values (0 1)	Converted Range of Values (%)	Linguistic Term
0–40	0–0.33	0–33	Short
40.1–80	0.33–0.66	33–66	Average
80.1–120	0.67–1	67–100	Long

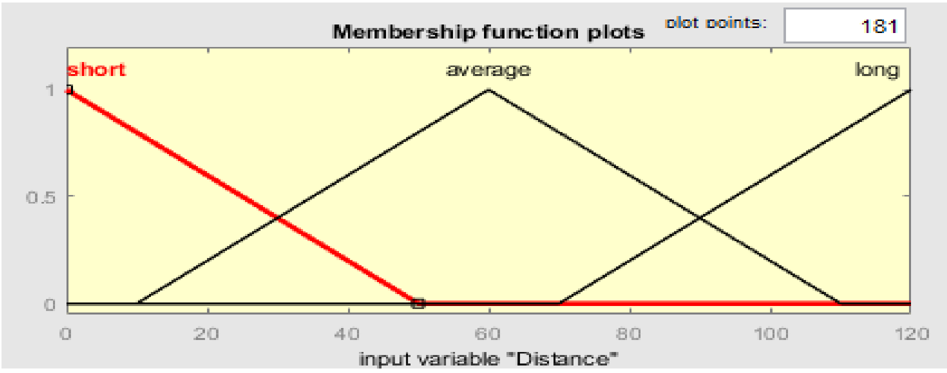

Figure 4: Input Membership (Distance).

Table 3: Input Membership - Engine (Capacity)

Range of Engine Values (Litres)	Fuzzy Values (0 1)	Converted Range of Values (%)	Linguistic Term
0–2.7	0–0.33	0–33	Small
2.8–4	0.35–0.5	35–50	Midsize
4.1–8	0.51–1	51–100	Big

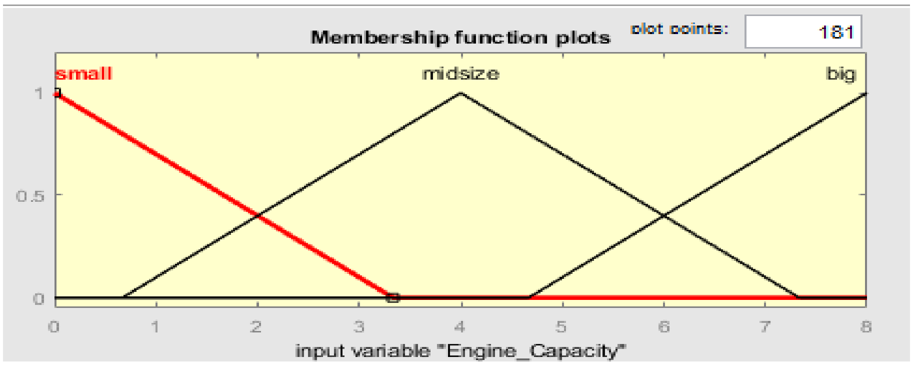

Figure 5: Input Membership - Engine(Capacity).

Table 4: Output Membership (Advice)

Output Variable	Range of Values	Linguistic Term
Advice	0–40	Excellent
	40.1–80	Good
	80.1–120	Bad

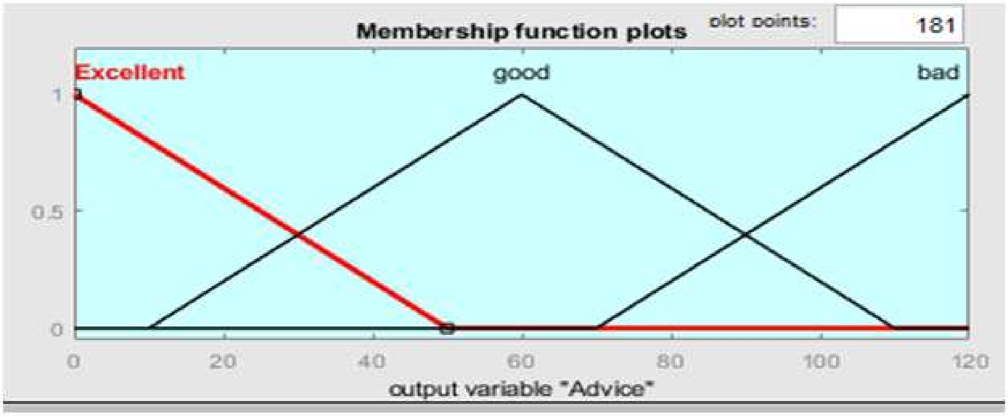

Figure 6: Output Membership (Advice).

6. EXPERIMENTATION

The model was implemented with 10 simulated drivers. Result can be found in appendix II. Sample graphical representations are shown in figures 7–9.

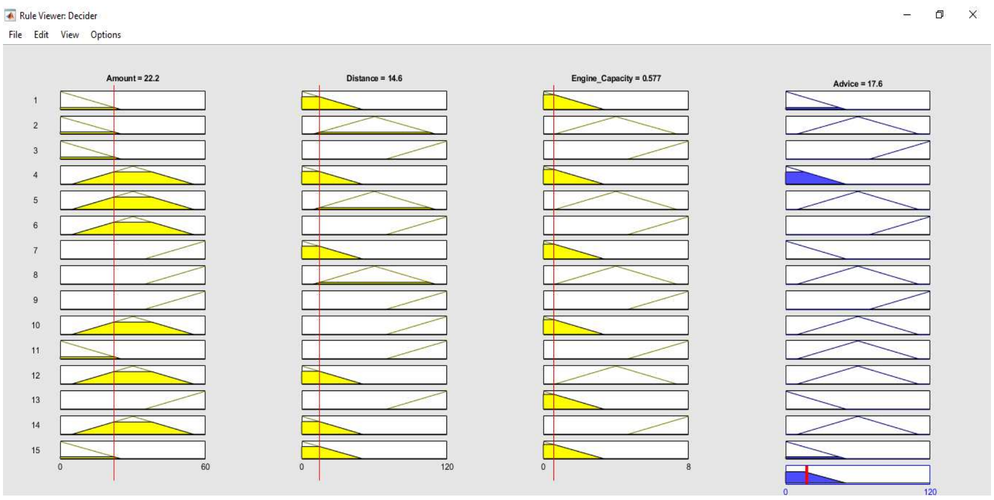

Figure 7: Simulated Results-Excellent.

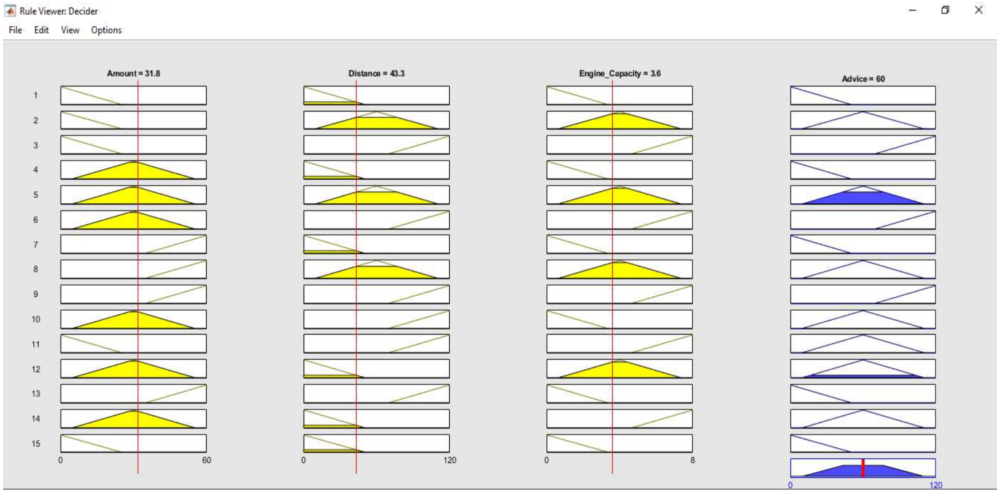

Figure 8: Simulated Results-Good.

Figure 9: Simulated Results-Bad.

7. COMPARATIVE ANALYSIS OF EXISTING AND NEW SYSTEM

This section compares the existing systems with the new system.

Table 5: Comparative Analysis of Existing and New System

Fuel Buying Decision Making Process for Drivers in Ghana	Fuzzy Logic Approach to Fuel Buying Decision for Drivers in Ghana
Step 1: Need Recognition by Driver **Step 2:** Information Search by Driver **Step 3:** Pre-purchase evaluation of the alternatives by Driver **Step 4:** Purchase by Driver **Step 5:** Consumption **Step 6:** Post Consumption Evaluation by Driver which can lead to Satisfaction or Dissatisfaction **Step 7:** Divestment	**Step 1:** Identify fuzzy input variables. **Step 2:** Put score on each variable **Step 3:** Fuzzify the inputs and store in Database **Step 4:** Define the fuzzy rules **Step 5:** Use the fuzzy system to evaluate the buying decision

7.1 Disadvantages of the Existing Approach

The existing system is a seven-step approach (see table 5) to determine the fuel buying decision by drivers without putting a score on each of the variable. It can be argued that the variables in the seven steps do not really represent the fuel buy decision of the drivers in Accra, it also discloses the stress and financial losses that the drivers can experience making a fuel buying decision.

7.2 Benefits of the New System

The new system assigns a score (weight) on each variable, as illustrated in table 5. Subsequently rules are defined to help in the evaluation which helps in determining excellent, good and bad decisions.

8. CONCLUSIONS AND RECOMMENDATIONS

This research was needed by the inherent problem faced by drivers in making a fuel buying decision in Ghana. The main objective of the study was to develop a fuel buying decision model to offset the challenges faced by drivers in Ghana using fuzzy logic.

8.1 Recommendations

Drivers should upgrade their Information Technology tools usage skills like smart phones and tablets. The ministry of transport can collaborate with the National Information Technology Agency to organise Information Technology training for drivers in Ghana. The model developed should be made available to drivers in Ghana for use to make fuel buying decisions. Human efforts should be limited as this leads to subjective judgment which would lead to wrongful decisions

The research found that, Fuzzy Logic is effective in modelling applications where human judgement is involved. Therefore, further studies can look at the decision by National Petroleum Authority to permit the construct of filling stations in Ghana. Also, further studies can use fuzzy logic to assess the range of vehicles that can be classified as luxury vehicles.

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Appendix I

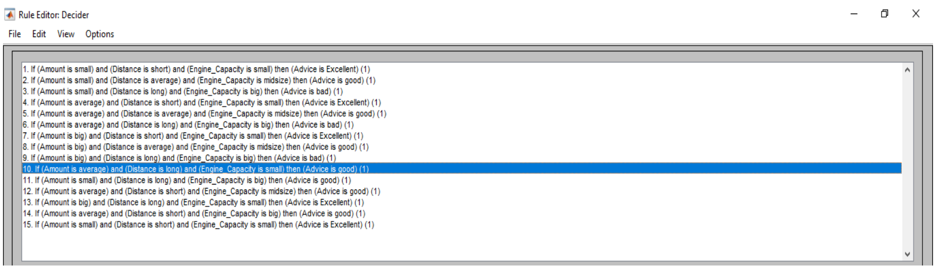

Figure 10: Inference Rules.

Appendix II

Table 6: Simulated Results

Name of Driver	Amount	Distance	Engine-Capacity	Advice	Buying Decision
Driver Y	12.4	39.7	0.736	29	Excellent
Driver A	28.8	60	3.72	60	Good
Driver X	46.7	82.7	7.26	92.5	Bad
Driver K	35.1	32.5	1.41	46.4	Good
Driver Z	48.2	84.5	7.3	96.3	Bad
Driver L	13.3	17.6	1.21	39.2	Excellent
Driver Q	50	83.9	7.18	88.2	Bad
Driver P	30.3	93.4	6.63	77.9	Good
Driver C	7.31	8.66	1.85	33.6	Excellent
Driver G	49.4	113	6.11	100	Bad